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December 9, 2008

Secretary
Federal Communications Commission
Washington, DC 20554

Re: ET Docket No. 04-37

Gentlemen,

Annex 2 to the attached document contains the following paragraph:

Distance separation The relation between field strength and distance was investigated to define both the size of the exclusion zone required to protect HF stations from PLT interference and the extrapolation factor to be used in the measurements. The field strength was measured at 3 and 10 metres for frequencies between 4 MHz and 30 MHz. The results demonstrated that a 40 dB/decade extrapolation factor represents a good first approximation. Nonetheless, the average measured reduction values were 2.3 dB higher than the calculated reduction values for line-of-site attenuation.

(emphasis added)

Sincerely,

Jeffrey Krauss

Attachment: ITU-R Document 1A/77

Source: Document 5C/TEMP/46

Document 1A/77-E
Document 5A/161-E
Document 5B/168-E
Document 6A/116-E
3 November 2008
English only

Working Party 5C

LIAISON STATEMENT TO WORKING PARTY 1A
(COPY TO WORKING PARTIES 5A, 5B AND 6A FOR INFORMATION)

INTERFERENCE ISSUES FROM POWER LINE TELECOMMUNICATION
SYSTEMS USING THE ELECTRICITY SUPPLY WIRING

1 Introduction

Working Party 5C thanks Working Party 1A for its liaison statement (Document [9C/158 \(study period 2003-2007\)](#)). In response, Working Party 5C presents studies in the Annexes of this document. Annex 1 presents a methodology for calculation of cumulative HF skywave interference from power line telecommunication systems. Annex 2 presents tests on the levels of groundwave signals from power line telecommunications (PLT, PLC).

Working Party 5C is still conducting studies into power line telecommunication systems and does not propose the adoption of protection levels with this document.

Working Party 5C would welcome any comments/contributions WP 1A may have in relation to the material annexed to this document.

(NOTE – If there are problems downloading the Matlab PLT tool files and population data provided in Annex 1, please send an e-mail to the contact person.)

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Annex 1

Methodology for calculation of cumulative HF skywave interference from power line telecommunication systems

1 Introduction

This Annex presents the results of the work carried out by the NATO Research & Technology Organisation Information Systems Technology (IST) Panel Research Task Group (RTG) on “HF Interference, Procedures and Tools IST-050/RTG-022”¹, to address the concerns raised by the potential for unintentional radio interference by the widespread operation of broadband wire-line telecommunication systems, such as power line telecommunications (PLT, PLC). The Research Task Group started their studies in 2004, with the participation of an international group of experts, and the final report was published in 2006 for unlimited public use.

2 Method of calculation for cumulative HF skywave interference from PLT systems

A comprehensive methodology is proposed to predict the cumulative effect of far field (skywave) PLT interference at a receiver location. Given knowledge of all relevant input parameters, the methodology would give accurate predictions. It is well established and easy to explain that the cumulative signal power from large number of unintentional radiators (e.g., PLT installations), as received at a receiver site, can be written:

$$P_{cum}(f, t) = \iint_{xy} \frac{g_{RX}(x, y, f)}{L(x, y, f, t)} P_{TX}(f) D_A(x, y) \eta_{PEN}(x, y) \eta_{USAGE}(t) dA \quad (1)$$

- $P_{cum}(f, t)$ is the total received power spectral density [W/Hz], at frequency f and time instant t .
- The integral is done over an area with geographical coordinates (x, y) .
- The integral (summation) is performed incoherently, i.e. on a power basis, rather than on an amplitude basis.
- $g_{RX}(x, y, f)$ is the receiver antenna directivity in the direction (azimuth and elevation) of signals originating from a transmitter at point (x, y) . It is important to use directivity rather than gain, in order to be able to compare the result to established background noise levels.
- $L(x, y, f, t)$ is the basic transmission loss from point (x, y) to the receiver site. For each frequency it varies with time (as function of solar activity and time of day and year). It is proposed to use the median transmission loss “LOSS” as predicted by ICEPAC2, which

1 The Report and “Cumulative PLT calculation Tool” can be downloaded from <http://www.rta.nato.int/Pubs/RDP.asp?RDP=RTO-TR-IST-050>.

2 ICEPAC is part of the IONCAP family of HF prediction programs, which are considered, according to Recommendation ITU-R F.1611, as related models to that contained in Recommendation ITU-R P.533. ICEPAC is available for download from: <http://www.itu.int/ITU-R/index.asp?category=documents&link=rsg3&lang=en>.

calculates a prediction of the amount that the PLT signal will be attenuated under *median* propagation conditions for the given input parameters.

- Note that ICEPAC can estimate $\frac{L(x,y,f,t)}{g_{RX}(x,y,f)}$ directly, if the receiver antenna characteristics are given, which in this case should be normalized by the antenna efficiency to give antenna directivity rather than gain. In the absence of knowledge of receiver antenna, an isotropic antenna can be assumed $g_{RX}(x,y,f) = 1$.
- $P_{TX}(f)$ is the average e.i.r.p. spectral density [W/Hz] of a single PLT installation.
- $D_A(x,y)$ is the population density (persons per unit area). Such demographic data (actual numbers from 2005 and predicted numbers for 2010 and 2015) can be downloaded free of charge from the database “Gridded population of the world”³. It is recommended to download “Population Grid” data, which contains the number of people in each grid square, at a grid resolution of 0.25 degrees in BIL format. These data implicitly take into account the different areas of grid squares at different latitudes (and that some grid squares have smaller land areas since they contain partly sea), and hence contain $D_A(x,y)dA$ directly.
- $\eta_{PEN}(x,y)$ is the market penetration (PLT installations per capita).
- $\eta_{USAGE}(t)$ is the duty cycle; the average fraction of time each PLT installation is transmitting. This will be different for different times of day and week; for home installations it is likely to be larger when people are not at work. When considering in-house PLT systems, the market penetration would refer to the number of modems installed, while the duty cycle be averaged over the number of modems (and hence will not exceed 50%, considering that there always will be at least one modem listening to a transmitting modem).
- To estimate the potential of cumulative effect of PLT interference at a receiver site, Working Party 5C recommends the following methodology:
 - 1) Download and import population density data $D_A(x,y)dA$.
 - 2) Estimate $\eta_{PEN}(x,y)$ based on available market information.
 - 3) Select a number of representative operating frequencies, times of day and year, sunspot numbers (SSN) and levels of geomagnetic activity⁴. For each combination of these, do the remaining steps.
 - 4) Run ICEPAC (ICEAREA_INV) to obtain median values of $\frac{L(x,y,f,t)}{g_{RX}(x,y,f)}$.
 - 5) Estimate values of $P_{TX}(f)$ and $\eta_{USAGE}(t)$, based on available information.
 - 6) Evaluate the integral numerically.
 - 7) Compare the result with the background noise level.

3 Socioeconomic Data and Applications Center (SEDAC), Columbia University, which can be downloaded from the following web site <http://sedac.ciesin.columbia.edu/gpw>.

4 Geomagnetic activity input (Q-index) which represents the effective geomagnetic activity index if the planetary magnetic index Kp is known. Q-index has a range of [0-8], 0 being quiet, 5 is active and 8 is a major storm condition.

3 Cumulative PLT tool

The user interface of ICEAREA INVERSE only allows sweeping over 9 different combinations of input parameters, which makes it cumbersome to perform comprehensive analyses. The number of input parameters is five (month, time of day, sunspot number, geomagnetic Q-index and frequency), such that the total number of parameter combinations easily exceeds 1 000, even with a modest number of alternatives for each parameter.

To overcome this problem, the Task Group has developed a MATLAB-based tool “cumulative PLT tool” which will bypass the ICEAREA INVERSE user interface and execute the program directly in batch mode for an arbitrarily large number of parameter combinations. The PLT Tool performs this by modifying the input files before issuing the DOS command in order to start the ICEPAC program without a user interface.

For each parameter combination, the cumulative PLT tool will perform items 1, 4, 6 and 7 in the methodology outlined in the previous section, and save the resulting cumulative PLT signal level to a text file which can easily be imported into Excel, MATLAB, or any other program for post-processing and display. The text file will also contain Recommendation ITU-R P.372-8 noise levels and the absolute protection requirement (APR) level. The task group proposed an absolute protection requirement of $-15 \text{ dB}\mu\text{V/m}$ per 9 kHz bandwidth is converted to dBm/Hz with the following equation for the protection of radio services from PLT generated interference:

$$APR(f) = (-15 \text{ dB}\mu\text{V/m}) - 20 \log_{10}(f) - 10 \log_{10}(b) + 95.5 - 174 \quad \text{dBm/Hz} \quad (2)$$

f : frequency (MHz) and

b : noise power bandwidth (Hz).

Also, under certain rare circumstances ICEPAC predicts path losses smaller than 30 dB from certain regions to the receiver site. This is clearly physically not possible, and is likely to be due to a flaw in ICEPAC. The cumulative PLT tool will discard any ICEPAC runs which predict the path loss to any region smaller than 50 dB, and tag the predicted cumulative PLT signal level as NaN (Not a Number) to indicate missing data. During testing of this tool NaN occurred at 107 out of a total of 7 992 ICEPAC runs.

Before running the tool, ICEAREA INVERSE should be run once in order to define receiver location and transmitter location grid, and set up the input files (which the tool will later modify) accordingly. The transmitter location grid must be a Latitude/Longitude grid with 0.25 degrees resolution in both directions, and the result should be saved in the “default\” subdirectory. The tool is equipped with a text-based user interface rather than a graphical user interface (GUI). Also $P_{TX}(f)$, $\eta_{PEN}(x, y)$ and $\eta_{USAGE}(t)$ are constant input parameters, such that variation in these parameters over frequency, location and time is not implemented.

4 Cumulative PLT tool – Instructions on use

Software files for the cumulative PLT tool can be downloaded from

<http://www.rta.nato.int/Pubs/RDP.asp?RDP=RTO-TR-IST-050>, and steps on how to use the tool are shown below.

To start using the tool, do the following:

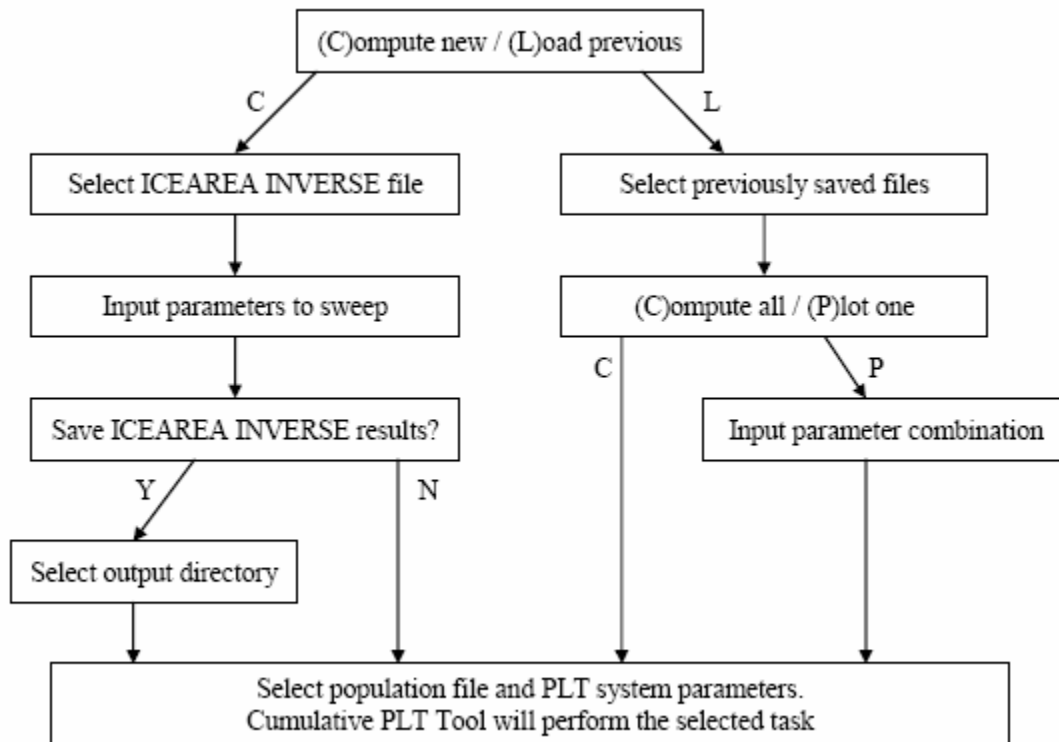
- 1) Run ICEAREA INVERSE once in order to set up the receiver location and transmitter location grid:
 - a) Start ICEAREA INVERSE.
 - b) Push “Parameters” LOSS (predicts the path loss directly).
 - c) Push “Method” Auto select.
 - d) Coefficients: URSI88 (no difference observed when using CCIR coefficients, but recommend using URSI88 since these are the newest).
 - e) Push “Receiver” to select a receiver location.
 - f) Push “Plot Center”, → “Set to receiver”, and select the X-range and Y-range for the transmitter grid. Ensure that the X-range and Y-range covers the same number of degrees. A grid of $-4\,000$ km to $+4\,000$ km should be sufficient, which is approximately the maximum distance for single-hop propagation, limited by the Earth’s curvature, unless interference from farther-away regions is of particular interest. (Examine the map to find proper values of minimum/maximum latitude and longitude. Ensure that the difference between maximum and minimum value is the same for latitude and for longitude such that the angular resolution becomes identical in both directions).
 - g) Push “Grid”, select Grid Type = “1 Lat/Lon”, and select the grid size such that each grid cell is 0.25×0.25 degrees, e.g. if X-range and Y-range cover 70×70 degrees, select a grid size of 281×281 . Lat/Long grid is convenient when used in conjunction with gridded population density data.
 - h) Select “Run” → “Map only” in order to see the extent of the transmitter grid.
 - j) Ensure that there is only one parameter combination under “Groups” (the actual parameter values here are irrelevant).
 - k) Push “System parameters”, Min. angle = 0.1 deg, multipath power tolerance = 10 dB, maximum tolerable time delay = 15 ms (the latter two values are increased from the defaults in order to account for different propagation paths). The other system parameters, including transmitter power, are irrelevant when predicting path loss only.
 - l) Push “Fprob” Keep default values.
 - m) Push “TX antenna” default/isotrope5.
 - n) Push “RX antenna” default/isotrope, or insert knowledge about antenna at the receiver location if required.
 - o) Select “Run” → “Calculate” → “Save/Calculate/Screen”.
 - p) When prompted for input file name, go to the subfolder named “default” and enter a meaningful file name.
 - q) The program should now perform calculations and produce a plot on the screen. Close the program and all windows it has generated. The files generated by the program will be used by the cumulative PLT tool.

NOTE – If only one case is selected under “Groups”, run “Save/Calculate/Screen”. The result will be output to a map on screen and saved to a file *xxx.ig1*. If several cases are selected under “Groups”, run “Save/Calculate”. The results will be saved to files *xxx.ig1*, *xxx.ig2*, *xxx.ig3* and so on. The output files *xxx.igx* are text files which can be used in further post-processing to evaluate cumulative effects.

- 2) Start MATLAB, go to the installation folder and enter “cumulative_plt_tool” in order to start the tool. Follow the on-screen instructions.
 - a) The input procedures are intended to be relatively failsafe; in case of unexpected inputs the tool should repeat the question.
 - b) The options of the text-based user interface are illustrated in Fig. 1.
 - c) When prompted to select population data file, note that, e.g., the file name *glp05ag15.bi* corresponds to population data from 2005, and *glp10ag15.bil* to 2010 (the middle digits of the file name denotes year).
 - d) Be aware that large amounts of processing time and hard disk space may be required if running a large number of parameter combinations.

FIGURE 1

Flowchart of the available options in the user interface of the cumulative PLT tool



The tool has three different modes of operation:

- 1) “Compute new”: The tool will go through a number of parameter combinations and do the following for each parameter combination:
 - a) Call ICEAREA INVERSE.
 - b) Store the result file generated by ICEAREA INVERSE for later use (optional).
 - c) Estimate the cumulative PLT signal level and compare with ITU-R noise curves and with the absolute protection requirement.
 - d) Write the resulting numbers to a text file.
- 2) “Load previous/Compute all”: The tool will go through files previously generated by ICEAREA INVERSE under mode 1, and do the following for each file:
 - a) Load ICEAREA INVERSE result file into memory.
 - b) Estimate the cumulative PLT signal level and compare with ITU-R noise curves with the absolute protection requirement.
 - c) Write the resulting numbers to a text file.
- 3) “Load previous/Plot one”: The tool will prompt the user to select one of the previously computed parameter combinations and produce the type of figure/map shown in Fig. 2.

The following files are produced when running the tool:

- 1) “xxx_summary.txt”: Text file containing the estimated cumulative PLT signal level compared to background noise curves for each parameter combination.
- 2) “xxx_swept_parameters.mat”: MATLAB data file containing information on which parameter combinations were simulated (to be used in the “Load previous” modes).
- 3) (Optional) “xxx_00001.ig1”, “xxx_00002.ig1”, and so on: Results generated by ICEAREA INVERSE (one file per parameter combination).

5 Calculation of HF radio noise from PLT systems

In this section an example where the cumulative PLT tool is used to evaluate the interference potential at a hypothetical receiver location. The location was selected on the basis that it should be a city for easy reference. The input parameters are given as an example in section 5.1.

5.1 Example receiver location in Winnipeg, Canada

In this example, a hypothetical receiver location at Winnipeg Canada (49.53N and 97.09W) was used. The analysis is performed under the following assumptions:

Average EIRP per PLT installation is $P_{TX} = -80$ dBm/Hz (e.g. -50 dBm/Hz HomePlug modems and equivalent antenna gain from wiring of -30 dBi).

Market penetration is $\eta_{PEN} = 0.05$ PLT modems per capita.

Duty cycle of each modem is $\eta_{USAGE} = 0.3$.

The transmitter location grid used extends from -120 to -50 degrees longitude and -15 to 55 degrees latitude, and PLT modems outside this area are disregarded. No knowledge of receiver antenna characteristics is assumed, hence an isotropic receiver antenna is used in the analysis.

A population data prediction from 2010 is used.

Cumulative PLT tool execution within MATLAB is shown below:

Cumulative PLT Tool

Roald Otnes, Norwegian Defence Research Establishment (FFI), October 2006
NATO RTO IST-050/RTG-022 on HF Interference, Procedures and Tools

This program will estimate the cumulative effects from PLT,
based on ICEPAC sky wave path loss predictions and population data
from "Gridded population of the world" (gpwv3) database

The program has been tested on MATLAB versions 6.5 and 7.1,
and with ICEPAC version 05.0119WW

Please run ICEAREA INVERSE one time as normal to set up all parameters, before
running this program to sweep some of the parameters.
ICEAREA INVERSE will then be called (batch mode) for all chosen parameter combinations.

Use of text-based interface:

Enter will provide default parameters.
Use MATLAB syntax for the parameters to be swept.
Be aware that using default values for all swept parameters will take very long time to run.
Ctrl-C in MATLAB window to abort.
Do NOT close down the ICEPAC window that pops up; that will make Windows confused.
ICEAREA INVERSE batch calculation: (C)ompute new or (L)oad previous? c
ICEPAC installation directory [c:\itshfbc\]:
Select the input file created from the initial setup run (eg. WINNIPEG.ice)
ICEPACfile =
WINNIPEG
Swept months [2:2:12]: 2:2:12
Swept UTCs [0:4:20]: 0:4:20
Swept SSNs [50 100 200]: [50 100 200]
Swept Qs [0 5]: [0 5]
Swept freqs [2 4 8 16 24]: [2 4 8 12 16 20 24]
Total number of ICEAREA INVERSE runs planned: 1 512
Save ICEAREA INVERSE results for later use (disk space required: 20 267.1 MB). [Y]/N? Y
Output directory [.\ICEPAC\]:
Select population file (eg. glp10ag15.bil for 2010 data)

EIRP per PLT modem (dBm/Hz) [-80]:
Market penetration (PLT modems per capita) [0.05]:
Duty cycle (fraction of time each PLT modem is transmitting) [0.3]:
Market factor (penetration * duty cycle): -18.2 dB
EIRP per capita: -98.2 dBm/Hz

Results will be saved to file .\icepac\WINNIPEG_summary.txt
Modifying ICEAREA INVERSE input files
copy c:\itshfbc\run\temp1.txt c:\itshfbc\run\iceareax.da1
1 file(s) copied.
copy c:\itshfbc\run\temp2.txt c:\itshfbc\area_inv\default\WINNIPEG.ice
1 file(s) copied.
c:\itshfbc\bin_win\icepacw.exe c:\itshfbc\INV CALC default\WINNIPEG.ice
copy c:\itshfbc\area_inv\default\WINNIPEG.ig1 .\icepac\WINNIPEG_00001.ig1
1 file(s) copied.

Integral of population / loss over entire area: -31.4 dB

Received PLT noise: -129.7 dBm/Hz

Atmospheric noise lower limit: -159.7 dBm/Hz

Man-made, rural: -115.0 dBm/Hz

Man-made, quiet rural: -129.0 dBm/Hz

Absolute protection requirement: -139.1 dBm/Hz

and so on for 1 511 other parameter combinations.

The MATLAB command window presented above starts with documentation and usage explanation followed by user input parameters and brief reports from individual ICEPAC runs. The first of 1 512 runs (for 6*6*3*2*7 parameter combinations) is shown above, The 1 512 ICEPAC runs with the 281 × 281 grid used in this example took a total of about 22 hours on a standard desktop computer circa 2006, and filled 20 GB of disk space when the detailed ICEPAC results were saved (optional) for later use.

As the input value “EIRP per PLT modem” is bandwidth normalized and given in units of dBm/Hz, the resulting estimate of the cumulative PLT signal is also given in units of dBm/Hz. The results are saved to a tab-separated text file, one line per ICEPAC run, similar to the WINNIPEG example given in section 5.1. (NOTE – In the case of discarded ICEPAC runs, the number in the “PLT noise” column will be replaced by “NaN”):

WINNIPEG [ISOTROPE], 2010 population data, EIRP = -98.2 dBm/Hz per capita

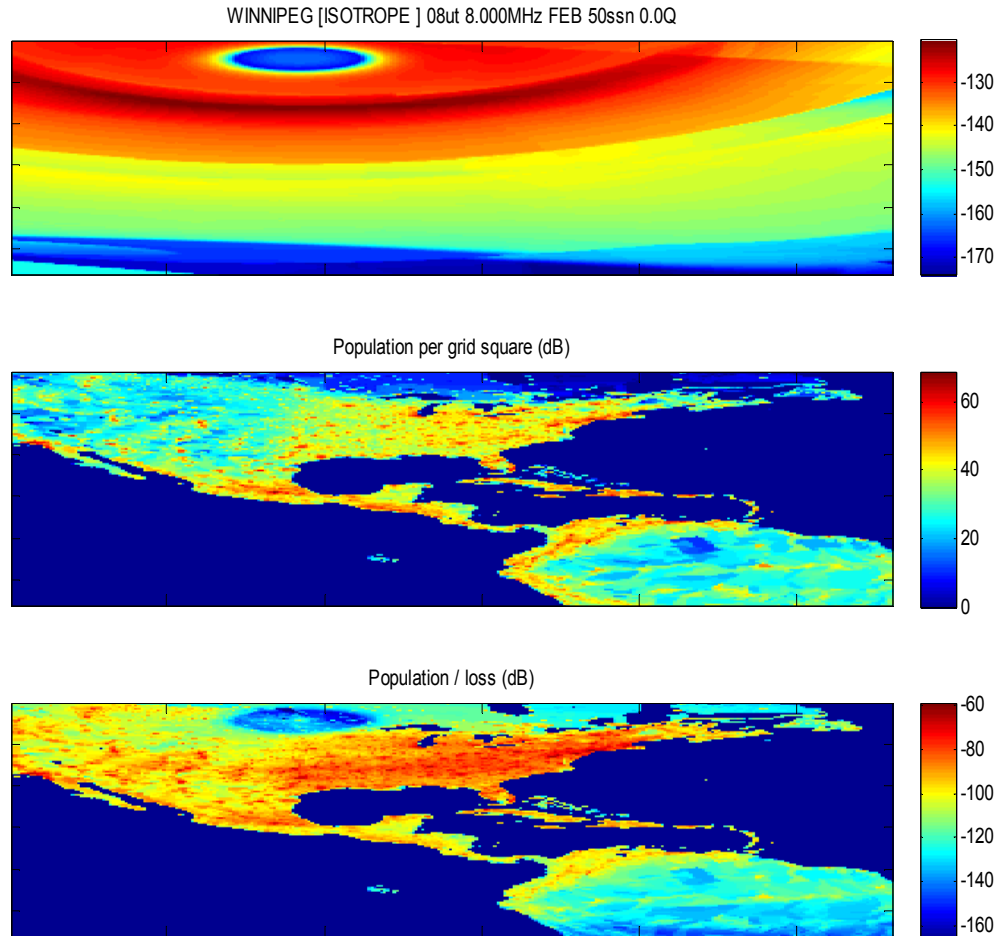
Month	UTC	SSN	Q	Freq	PLT noise	Atm (low)	Rural	Quiet rural	Abs. prot. req.
2	0	50	0	2.000	-129.69	-159.65	-114.99	-129.01	-139.06
2	0	50	0	4.000	-134.53	-152.37	-123.18	-137.62	-145.08
2	0	50	0	8.000	-139.32	-146.21	-131.36	-146.23	-151.10
2	0	50	0	16.000	-149.54	-160.64	-139.55	-154.84	-157.12
2	0	50	0	24.000	-165.75	-187.36	-144.34	-159.87	-160.65

5.2 Cumulative PLT output maps

The cumulative PLT tool also provides the option of plotting “maps” illustrating the correspondence between ICEPAC path loss and population density. This requires that the detailed ICEPAC results have been saved to disk. An example for a case where the predicted PLT signal exceeds the median quiet rural man-made noise by more than 6 dB is shown in Fig. 2. In general, high predicted PLT signal levels correspond to cases where there is low path loss from densely populated regions.

FIGURE 2

Top plot: Median path loss (dB) as predicted by ICEPAC for a combination of input parameters for a receiver in Winnipeg; Middle plot: Population per 0.25×0.25 degrees grid square in dB ($10\log_{10}(\text{population})$); bottom plot: Product (dB-sum) of the top two plots



The maps in Fig. 2 are generated using the MATLAB cumulative PLT tool as shown below:

ICEAREA INVERSE batch calculation: (C)ompute new or (L)oad previous? L

ICEPACfile =

WINNIPEG

(C)ompute cumulative PLT noise for all files, or (P)lot One? p

Select UTC, one of (0 4 8 12 16 20): 8

Select Freq, one of (2 4 8 16 24): 8

EIRP per PLT modem (dBm/Hz) [-80]:

Market penetration (PLT modems per capita) [0.05]:

Duty cycle (fraction of time each PLT modem is transmitting) [0.3]:

Market factor (penetration * duty cycle): -18.2 dB

EIRP per capita: -98.2 dBm/Hz

Month: 2 / UTC: 8 / SSN: 50 / Q: 0 / Freq: 8.00
Integral of population / loss over entire area: -41.3 dB
Received PLT noise: -139.6 dBm/Hz
Atmospheric noise lower limit: -146.2 dBm/Hz
Man-made, rural: -131.4 dBm/Hz
Man-made, quiet rural: -146.2 dBm/Hz
Absolute protection requirement: -151.1 dBm/Hz

6 Wire-line system antenna gain

The antenna gain of a wire-line transmission system is defined as the ratio between EIRP and injected power. For PLT systems, several measurement results were reported in the literature and RTG report recommends following antenna gains:

- -30 dBi for in-house systems;
- -15 dBi for overhead access systems;
- -50 dBi for underground access systems.

It should be recognized that there are uncertainties in these numbers of the order of ± 5 to ± 10 dB due to statistical spread. Furthermore, in the case of overhead Access system power lines, at resonant frequencies the antenna gain may be higher by 10-13 dB.

7 Current PLT market penetration estimation

In section 5 an estimated value of market penetration of $\eta_{PEN} = 0.05$ was used for the example calculations. Market information is generally difficult to obtain and hard to predict into the future, since vendors do not disseminate this information readily, and the technology is still in development. An attempt to predict the market development for PLT is given in [1], which predicts that by 2010 there will be between 2.5 and 5 million Access PLT (BPL) subscribers in USA. This corresponds to a market penetration of 0.9-1.7% of the population. In Germany, the number of HomePlug devices “on the market” in February 2005 was 300 000, and in February 2006 was 800 000 [2]. This information was given to the Task Group from the German BITKOM (industry) via the German Ministry of Commerce. The population in Germany was 82 million, thus the HomePlug market penetration as of February 2006 is 0.01 modems per capita. As of April 2006, Intellon had sold 10 million HomePlug chipsets worldwide and shipped 5 million of those. [3] (Intellon, DS2 and Panasonic are major vendors of PLT chipsets). Users of the cumulative PLT tool can enter appropriate value for this parameter.

8 Conclusions

The absolute protection requirement is a term developed by the research task group, and has been retained in this document to preserve the integrity of the cumulative PLT tool. The absolute protection level does not affect the calculations and it is used only for comparison, similar to how the various environmental noise levels are used. Working Party 5C has not concluded studies on protection levels for terrestrial radio services from PLT systems. The methodology presented in this document is based on the ICEPAC propagation prediction method, and can be used to predict cumulative HF skywave interference from PLT systems. This technique can be utilized to analyze impact of PLT signals received at a receiver location for terrestrial radiocommunication interference studies.

9 References

- [1] G. Held: "Understanding Broadband over Power Line", Auerbach Publications, 2006.
- [2] BITKOM-Informationen zu Anwendungen der Powerline-Technologie, Stand März 2006.
- [3] BPL Today, April 11, 2006, p.3.

Annex 2

Measurement of signal levels from HF groundwave power line telecommunication systems

1 Preliminary considerations

This Annex presents measurements and field test from Broadband Power Line communication systems reported by Brazilian Administration. Brazil has recently launched a public consultation to towards new regulations on PLT usage.

2 General information

Due to the increase in the demand for broadband Internet applications, power line telecommunications (PLT) arise as a technology that may supply this growing market. Electric power utilities intend to provide capacity to the telephone companies and telecom providers by means interested on the use of PLT technology to expand its capability.

The Brazilian Administration performed the tests in order to evaluate the effectiveness of mitigation techniques implemented in second-generation PLT systems. The aspects of radio interference and levels of radiated emissions from the PLT network were considered.

The Brazilian Administration is considering regulation, rules and necessary requirements to enable the coexistence of PLT systems, operating over low voltage (LV) and medium voltage (MV) power lines on the frequency band of 1.705 MHz to 50 MHz, with HF licensed systems.

3 Field measurements

3.1 Test configuration

The tests were performed on a typical low voltage installation and its main characteristics were:

- Overhead lines with 240 metres length.
- The network consisted of public lighting poles (to minimize motors and electrical appliances noise).
- Methodology applied based on ITU-T K.60 [5] and FCC 04-245 [7] procedures.
- Maximum output power level set around -50 dBm/Hz (to maximize disturbance emissions).
- A calibrated loop antenna, a tripod and a spectrum analyser were used (to measure the magnetic component of the radiated emissions below 30 MHz).
- Measurements were performed at a horizontal separation distance of 3 metres.
- Testing was performed along the line from the PLT injection point at 0, 1/4, 1/2, 3/4, and 1 wavelength spacing, based on the mid-band frequency used by the equipment.
- Three measurements were taken at each position (to ensure orientation of the magnetic loop antenna to provide the three orthogonal field components measurements).

Some results obtained showed that when the equipment is set at maximum injected power, the electric field is far above the FCC quasi-peak and ITU-T K.60 peak limits. Distance correction was applied to the FCC limit value according to the extrapolation factor adopted in FCC rules. When scanning the spectrum with and without the presence of PLT, it can be noted that the PLT signal interferes in the existing services. However, there is a considerable reduction in the radiated power when moving down the line from the injection point.

Regarding interference mitigation, three possible configurations were analysed:

- Notch Filters – They were configured to attenuate the signal level on predetermined frequency bands (4.8-4.9 MHz, 14-15 MHz and 22-23 MHz). In all three ranges, the emission strength falls below the levels given in ITU-T K.60 and it was confirmed the effectiveness of this mitigation technique in preset exclusion bands.
- Distance separation – The relation between field strength and distance was investigated to define both the size of the exclusion zone required to protect HF stations from PLT interference and the extrapolation factor to be used in the measurements. The field strength was measured at 3 and 10 metres for frequencies between 4 MHz and 30 MHz. The results demonstrated that a 40 dB/decade extrapolation factor represents a good first approximation. Nonetheless, the average measured reduction values were 2.3 dB higher than the calculated reduction values for line-of-site attenuation.
- Power reduction – The injected power was attenuated until the radiated emission reached the FCC limits and the results showed small increase in background noise due to PLT.

4 Measurement detector

Measurements could be made using CISPR 16-1-1 quasi-peak detector according to the ITU-T K.60 measurement procedure. Radiated emission testing must be done in a typical field installation, from the injection point and along the line.

5 Conclusion

Tests showed that the implementation of the necessary mitigation techniques in PLT systems should offer effective protection to HF systems.

As there are still regions in some countries that have no available infrastructure for broadband access, PLT implementation could complement other public initiatives so as to improve health care and promote digital inclusion.

The parameters identified based upon the Brazilian Administration's trials and the Brazilian Draft Regulation under consideration for public consultation in that country may be useful to other administrations intending to regulate PLT access systems.
